Overview of Currently Available UIT-Like Systems

The market for Distributed Generation (DG), or more broadly Distributed Energy Resources (DER), continues to evolve. DER units are increasingly being evaluated by residential, commercial, and industrial users as solutions for their energy needs. In addition, the DER retrofit market shows great potential. With energy market restructuring, DER units can be interconnected with the grid and standby capability can be expanded to provide peak shaving, interruptible rate, and export-to-utility functions.

Interconnecting DER to the grid can offer several benefits, which include:

- Giving the customer the flexibility to use the DER unit, the grid, or both;
- Providing the customer flexibility to take advantage of special electric rate structures;
- Taking advantage of the opportunity to export power to the Area Electric Power System (EPS), or to the power pool in deregulated markets;
- Improving overall customer reliability by providing an alternative power supply option; and
- Obtaining backup power from the EPS in the event of a DER system outage, eliminating the need for complete system redundancy.

Realization of the associated benefits of DER depends on DER's successful integration into the utility or Disco EPS distribution system operations without any negative impacts on system reliability or safety.

The Need for a Universal Interconnection Technology

An interconnection system is the equipment that makes up the physical link between DER and the EPS, usually the local electric grid. The interconnection system is the means by which the DER unit electrically connects to the outside electrical power system, and provides for monitoring, control, metering, and dispatch of the DER unit. In short, the interconnection devices perform the functions necessary to maintain the safety, power quality, and reliability of the EPS when DERs are connected to it.

The complexity of the interconnection system depends on the level of interaction required between the DER, the customer loads, and the EPS. Typically, complete systems that allow a DER unit to parallel with the grid include the following components, which may or may not be modular:

- Exciter control system for the generators,
- Synchronizer for the reliable transfer of power between the generators and the grid,
- Automatic transfer switch control,
- Import/export control,
- Protective relay functions including over/under frequency and voltage at the interconnection points, directional real and reactive power flow, and phase-to-phase current balance,
- Metering or net metering, depending on the tariff, and
- Remote communications capabilities to accommodate control from remote control centers (e.g., direct transfer trip, in some cases).

Different applications of DER require different levels of interconnection complexity, and most interconnection today is still performed on a site- and DER unit-specific basis. This greatly increases the cost compared with what it would be if the interconnection system were standardized. Beyond this, the lack of standardization of interconnection systems can be confusing for DER users and deter them from interconnecting with the grid.

For these reasons, there has been substantial interest recently in developing a Universal Interconnection Technology (UIT). Development of a UIT would define a standard architecture for functions to be included in the interconnection system. This standard architecture would allow both DER manufacturers and end-users to easily integrate their power systems with the area EPS.

A Universal Interconnection Technology would include at least the following functions:

- Power conversion,
- Power conditioning and quality,
- Protection functions,
- Synchronization,
- DER (both generation and/or storage) and load controls,
- Communications,
- Metering, and
- Dispatch.

Other useful features could include the ability to provide ancillary services to the distribution system and the ability to communicate back to the utility the status of the distribution system.

Underlying development of a UIT are advances in interconnection components and in integrated power electronics. Electromechanical "discrete" relays, which dominated utility interconnection, protection, and coordination for years, are being supplanted by digitally based equipment, frequently with multi-function capability. Utilities themselves are gravitating towards digital, programmable relays, raising the issues of field calibration and certification. The rise of inverter technology as an alternative to rotating power conversion technology (i.e., induction and synchronous generators) has opened the door to integrated, inverter-based protective relaying.

In summary, a modular UIT will make DER installation cheaper, quicker, more reliable, and will also provide benefits to the distribution company.

Current UIT-Like Systems

Some third-party manufacturers are assembling systems of components to build complete interconnection systems that meet some of the UIT vision. There are two types of UIT-like systems currently in development:

- *Traditional non-inverter based pre-engineered systems* that allow for synchronization and parallel operation with the grid. Often these assemblies are referred to as "switchgear", where all the necessary components are built into either panelboards, switchboards or other suitable cabinets; and

- *Inverter based UIT-like systems* for prime movers with DC or high frequency AC output (i.e. PV systems and fuel cells). These systems can also work with standard induction and synchronous generators.

These types of interconnection systems exist for both new DER and for the retrofit of existing DER units of various manufacturers.

Traditional Non-inverter Based Switchgear Pre-engineered Systems

Non-inverter based interconnection systems use microprocessor based digital controllers to synchronize and parallel DER unit operation with the grid. Often called "switchgear," these systems are single pre-engineered structures that contain the many functions necessary for synchronization and parallel operation with the grid: operator interface, controls, protective relays, circuit breakers, and much more. Unlike inverters, these systems are generally used for DER units with more traditional AC output such as reciprocating engines, and do not provide for power conversion with inverters.

One goal is to develop switchgear that can be universally applied. Several models on the market have achieved that goal. These units focus on simplified system installation, and work with different styles or brands of generators. These UIT-like systems can be used for new DER units or to transform existing standby units to provide peak shaving, interruptible rate, and export-to-utility functions. Units are available from companies such as Detroit Diesel (SD-100), ZTR/ Shallbetter (DGX Switchgear), Kohler (PD-100), and several others.

Several switchgear systems integrate components from multiple manufacturers. For example, the ZTR/ Shallbetter DGX Switchgear uses a digital controller from Woodward, protective relaying from Schweitzer (for utility relays) and Woodward (for genset relays), and monitoring systems and software from ZTR. Kohler's PD-100 switchgear/ paralleling switchgear system, which converts new or existing standby generators (from 20-2,000 kW) into peak shaving, prime power or electricity exporting units, uses a controller from Encorp. A single line diagram of Kohler's unit is shown below.

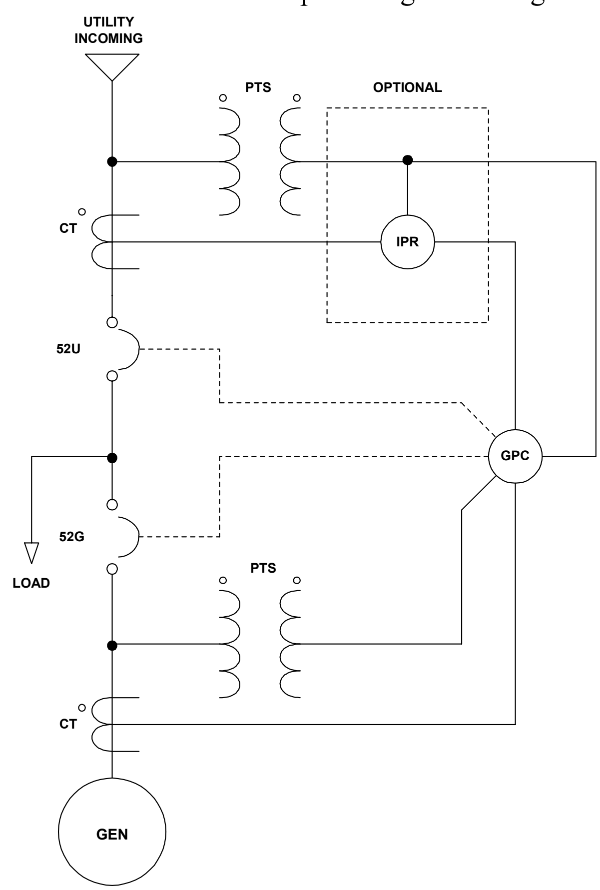

Figure 1. Switchgear Single Line Diagram (Kohler PD-100)

Inverter Based Systems

The inverter based UIT-like systems is designed for use with prime movers with DC or high frequency AC output (i.e. PV systems, wind, fuel cells, and microturbines). These technologies are expected to increase their share of total power produced in the United States and abroad, setting the stage for inverter based UIT-like systems to interface DC power sources with the grid. Microturbines, which produce high frequency AC, are well suited for use with inverter based UITs since their rectified output (i.e., DC) can be directly fed to the inverter, which then converts it to 60-Hz AC.

The Department of Energy, through the Oak Ridge National Laboratory, recently published a White Paper entitled "*White Paper on the Development of the Universal Inverter for Distributed Energy Resources.*" This paper outlines concepts and designs for the development of a universal inverter. The paper determines that for present-day inverters to meet the requirements of a UIT, several issues must be addressed. These include:

- Switching device ratings (and associated reliability issues),
- Transformers (and associated design limitations),
- Lower cost,
- Control limitations,
- Limitations on voltages that can be attained, and
- Creation of high levels of harmonic distortion.

In addition, DG inverters will be required to at minimum provide services such as voltage regulation, frequency regulation, and reactive power supply.

The DOE White Paper focuses on the importance of modular inverter systems. Advanced Energy Systems offers two inverter based interconnection systems, one for residential and small commercial power systems (PV and wind power) and the other for entry-level grid-tied, battery-less photovoltaic systems. These units meet UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection. Another currently available inverter based UIT–like model is Ballard's EcoStar Power Converter, which is designed to operate with microturbines. A diagram showing the modular building blocks of an inverter based UIT system is shown below.

Inverter systems also integrate components from multiple manufacturers. AstroPower SunChoice program offers two grid-tie PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).

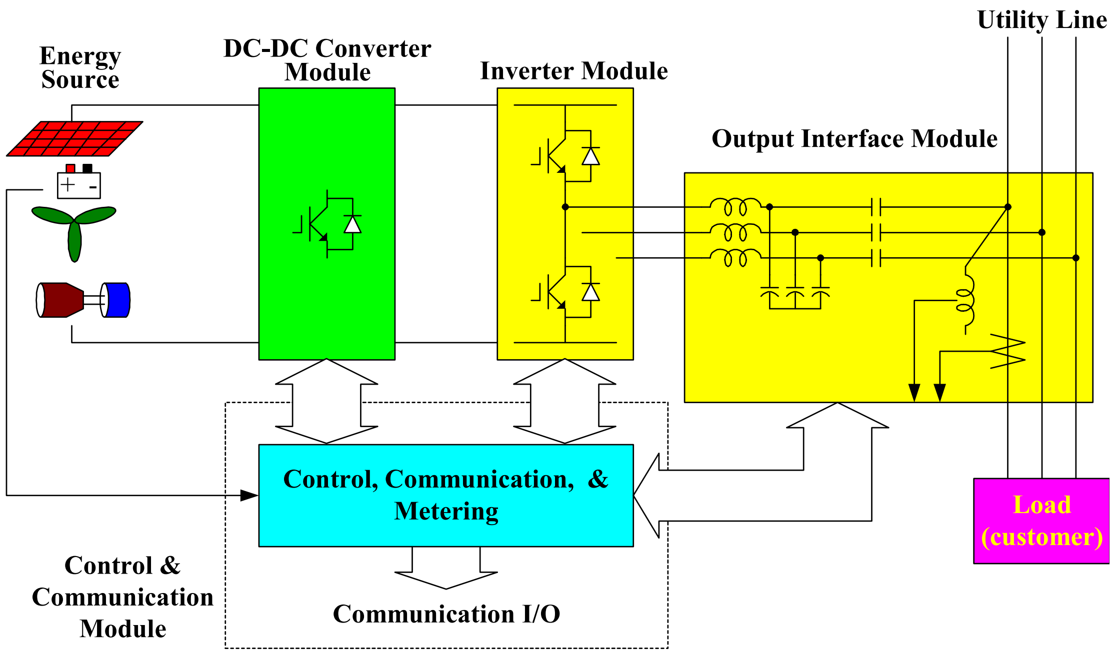

Figure 2. Universal Inverter Modular Building Blocks

In the future, inverter based interconnection systems may be applied to standard reciprocating engine gensets. Benefits include higher efficiency and lower emissions at part load. Honda currently manufacturers a 3,000 watt genset whose generator produces 200 volts at 14 to 17 Hz, which is converted to 12 volts DC, and then inverted to 50 or 60 Hz AC. Honda claims a higher power quality than standard gensets.

Current Products

Table 1 lists some of the UIT-like systems currently on the market. These systems will need time to truly obtain the goal of "universal" status; meanwhile they highlight market developments.

Table 1. Currently Available UIT-Like Systems

Company	Unit	Inverter	Non-Inverter	Electrical Specification
Advanced Energy Systems	*MM-5000 – Grid-Connected MultiMode Power Conversion System*	X		5 kVA
	GC-1000 1kW Grid-Connected Photovoltaic Inverter	X		1 kVA
AstroPower	*SunChoice Program*	X		8.5 kVA
Ballard	*EcoStar Power Converter*	X		Up to 110 kVA
Cummins Power Generation	*PowerCommand Digital Paralleling Equipment*		X	Up to 2,500 kVA
Detroit Diesel	*Spectrum SD-100*		X	Up to 2,400 kVA
Encorp	enpower-GPC powered "paralleling switchgear"		X	800-5000 amp
Fire Wind and Rain Technologies, LLC	*Power Streak Inverter*	X		5kVA
Kohler	*PD-100 Switchgear*		X	Up to 2,500 kVA
Thomson Technology	*Distributed Generation Switchgear System/ GCS 2000-DG System*		X	Up to 4,000 amp
Vanner Incorporated	*RE Series Inverters*	X		5.6 kVA
Xantrex	*Grid Tie Inverters*	X		Up to 125 kVA
ZTR/Shallbetter	*DGX Switchgear*		X	Up to 4000 amp

Details of existing manufacturer product offerings, based on manufacturer-developed product literature, are now provided.

Advanced Energy Systems. Advanced Energy Systems has two grid-connected inverter based systems. The *MM-5000 – Grid-Connected MultiMode Power Conversion System* is a two-stage, DC to AC grid-tied inverter designed for residential and small commercial power systems (PV and wind power). It operates in stand-alone, grid-parallel, backup generator, and multi-unit modes with simplified programming and data retrieval, flexible operating modes, and intelligent user and wiring interfaces. It offers a fully integrated, single-box solution, including a charge controller, and all switchgear, a single reprogrammable microcontroller, and complete system control. Anti-islanding technology is available for operation in grid-parallel mode, and an input ground fault protection circuit provides improved operating safety.

The *GC-1000 1kW Grid-Connected Photovoltaic Inverter* is for entry-level grid-tied, battery-less photovoltaic systems. The inverter includes a string combiner, DC and AC disconnects, and ground fault interrupt protection. An optional interactive data monitor is also available. This system meets UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection.

AstroPower. AstroPower's SunChoice program offers two grid-tie PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).

Ballard. Ballard's *EcoStar Power Converter* is designed to operate with microturbines, although subsequent units will be targeted at internal combustion engines, PV systems, fuel cells, wind turbines, super capacitors and flywheels. The converter provides "electric grid compatibility," anti-islanding functions, parallel operation, and communication ports and protocols for units up to 110 KVA.

Cummins Power Generation. The Cummins *PowerCommand Digital Paralleling Equipment* includes all monitoring, protection, governing, voltage regulation, as well as all paralleling control functions including synchronizing, load sharing, and paralleling protection plus utility paralleling functions such as import/export control, and VAR and power factor control. Their *PowerCommand Network* is a Windows®-based, distributed system for local or remote monitoring and control, real-time data collection, retention, and report generation on generator sets, transfer switches, paralleling controls, switchgear, and other related power generation and distribution equipment. The combined system interfaces with all leading building management systems and automation packages.

Detroit Diesel. The Detroit Diesel *Spectrum SD-100* works with new or existing gensets in several modes including standby power, peak shaving, interruptible rate, and export-to-utility modes. The system includes operator interface, controls, protective relay, a circuit breaker (800-4,000 Amps) for paralleling, and monitoring functions for electric systems up to 600 VAC at 60 Hz.

Encorp. The Encorp *enpower-GPC* "paralleling switchgear" includes control modules, protective relays and network communications capabilities in a single, microprocessor-based "gold box." The system parallels one genset with the utility in base-load, peak-shaving, import/export or zero-power-transfer mode, and can be used for new gensets or for retrofit options. The *enpower-GPC* supports both the Modbus® and LONWORKS® communication protocols.

Fire Wind and Rain Technologies, LLC. This company's Power Streak Inverter can be used for grid tie or standalone application.. The Power Streak 4K is the first member of the Power Streak family of inverters/battery chargers based on a versatile modular inverter subsystem. It includes everything necessary for use including the inverter, weatherproof enclosure, DC and AC disconnects, Isolated Computer interface, remotable Liquid Crystal Display, Generator Control Modes and more. and is UL 1741/IEEE 519 compliant. The Power Streak is available with several input and output options including 48 or 120V DC inputs, and 120 or 240V outputs.

Kohler. The *PD-100 Switchgear/ Paralleling Switchgear system* is used to turn new or existing standby generators (from 20-2,000 kW) into peak shaving, primary power or electricity exporting tools. The system includes a circuit breaker (800-4,000 Amps), touch screen monitoring, control functions (the controller is manufactured by Encorp), protective relaying, and communications; for systems up to 600 VAC at 60 Hz.

Thomson Technology. Thomson Technology Inc.'s *Distributed Generation Switchgear System/ GCS 2000-DG System* is used for synchronizing single or multiple generators to the utility grid. The system incorporates control logic and software programming for automatic synchronizing, soft load transfer and automatic load (kilowatt) and VAR/PF control. It can work with a variety of industry standard communications for remote monitoring, control, and data logging, and can be used with either new systems or retrofits.

Vanner Incorporated. Vanner makes a series of inverters, including the RE Series, that accepts grid or generator input. The RE Series is designed specifically for alternative energy applications, and include multiple functions, including transfer switch, automatic generator control capabilities. The inverter has a 4500 Watt continuous output and is programmable with the Inverter/Charger Remote Control.

Xantrex Technology Inc. Xantrex manufactures utility interactive, three-phase inverters for solar arrays, with models ranging from 5 kW to 100 kW. Multiple inverters may be paralleled for larger power installations. Functions such as over- and under-voltage and frequency protection, anti-islanding protection, automatic operation including start-up, shut-down, self-diagnosis, and fault detection are included. The Grid Tie system consists of a solar array and the grid tie inverter, which includes all components necessary to make a grid connect system installation. The Trace™ ST Series inverters include the balance of system components for ease of installation.

ZTR. ZTR, in partnership with Shallbetter, Inc. produces the *DGX Switchgear,* which can be used for a genset paralleled to the utility, upgrading non-automatic switchgear, or for a genset retrofit. The system combines components from several manufacturers: a digital controller (Woodward EGCP-2), protective relaying (utility: Schweitzer, genset: Woodward EGCp-2 integrated feature), and monitoring via a ZTR-Lynx monitoring and supervisory control system. The switchgear is used for units up to 15 kV.

Built-in Systems

Many DER manufacturers have been either building in, or offering as an option, some of the key interconnection equipment components as part of their DER genset offerings. Some of these units, especially those incorporated into microturbines and fuel cells, have many of the same functionalities as a UIT.

In an effort to streamline the interconnection approval process, the California Energy Commission has established Type Testing and Production Testing requirements for equipment under its Rule 21 program. Systems that meet these requirements are considered to be Certified Equipment for purposes of interconnection with the distribution system. Rule 21 certification may apply to either a pre-packaged system or an assembly of components that address the necessary functions. Thus far, DER manufacturer systems are the only systems to be certified though it seems likely that UITs could benefit from this process as well.

Plug Power's Model SU1PCM-059622 5kW stationary fuel cell system was recently certified to comply with the Rule 21 requirements. Capstone's Model 330, 30 kW microturbine generator and Model 60, 60 kW microturbine have also been certified to Rule 21. These systems, like a UIT, contain all the components necessary for interconnection.

Future UIT Functions and Features

An issue for any UIT is its ability to provide certain functions and features. As a starting point, any UIT must provide safe interconnection with the EPS including all the necessary functions previously mentioned (power conversion, power conditioning and quality, protection functions, synchronization, DER and load controls, communications, metering, dispatch, ancillary services, and communication of the status of the distribution system) – all without harming grid reliability or power quality.

Beyond these functions there are a number of features that should exist in a UIT. Some features are listed below:

1. Adaptability

The ease with which a system satisfies differing system constraints and user needs.

2. Affordability

To have a cost which is bearable. For a UIT system, the cost of the interconnection component is a small part of the overall installed DER system cost.

3. Availability

The degree to which a system is operational and accessible when required for use.

4. Compatibility

The ability of two or more systems or components to jointly perform their required functions while sharing the same hardware or software environment.

5. Dependability

That property of a system such that reliance can justifiably be placed on the service it delivers.

6. Extendability or Expandability

The ease with which a system or component can be modified to increase its storage or functional capacity.

7. Evolvability

The ease with which a system or component can be modified to take advantage of new (internal) software or hardware technologies.

8. Flexibility

The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed. For interconnection systems, the ability to adapt to:

- New types of DG prime movers,
- Emerging storage platforms,
- New applications (e.g., ancillary services),
- Diverse distribution systems,
- New communications protocols.

9. Generality

The degree to which a system or component performs a broad range of functions.

10. Interoperability

A system than can exchange information with and use information from other systems.

11. Modularity

A modular interconnection architecture divides the interconnection system into discrete components (building blocks) each performing standard functions like the following:

- DER control,
- Power conversion,
- Voltage regulation,
- Power quality,
- Protection,
- Synchronization,
- Communications/control with load,
- Metering,
- Dispatch, and
- Area EPS communications and support.

The definitions of the modules should be generic enough to apply to both inverter and non-inverter systems, so that they have common building blocks. Not all interconnection systems will require all blocks.

12. Maintainability

The ability of a system, under stated conditions of use, to be retained in, or restored to, a state in which it can perform a required function.

13. Modifiability

The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined.

14. Portability

The ease with which a system or component can be transferred from one hardware or software environment to another.

15. Reliability

The ability of a system to perform a required function under stated conditions for a stated period of time.

16. Scalability
The ability to incrementally add functionality to a system without replacing it completely. Scalability means that an interconnection system designed for one application (e.g., peak shaving) may be "scaled up" by adding additional modules for a more complex application (e.g., utility dispatch).

17. Survivability
The degree to which essential functions are still available even though some part of the system is down.

18. Vulnerability
The degree to which a software system or component is open to unauthorized access, change, or disclosure of information and is susceptible to interference or disruption of system services.

One goal of the UIT Workshop is to review how well existing technology provides these functions and features, and where there are gaps in existing technology. In answering this, there may well be differences in the new generator and retrofit markets.